09/913502

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

HARRISON GODDARD FOOTE
Tower House
Merrion Way
Leeds LS2 8PA
ROYAUME-UNI

Date of mailing (day/month/year) 21 August 2001 (21.08.01)	
Applicant's or agent's file reference CTV/P45133WO	**IMPORTANT NOTIFICATION**
International application No. PCT/GB00/00521	**International filing date** (day/month/year) 17 February 2000 (17.02.00)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address

NEWCASTLE UNIVERSITY VENTURES LIMITED
Sun Alliance House
35 Mosley Street
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United Kingdom

State of Nationality	State of Residence
GB	GB

Telephone No.

Facsimile No.

Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[X] the person [ ] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address

PROTENSIVE LIMITED
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State of Nationality	State of Residence
GB	GB

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Facsimile No.

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3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer R. Chrem Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 23 October 2000 (23.10.00)	
International application No. PCT/GB00/00521	**Applicant's or agent's file reference** CTV/P45133WO
International filing date (day/month/year) 17 February 2000 (17.02.00)	**Priority date** (day/month/year) 17 February 1999 (17.02.99)
Applicant RAMSHAW, Colin et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

15 September 2000 (15.09.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer R. Chrem
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

P/ NT COOPERATION TREA

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

HARRISON GODDARD FOOTE
Tower House
Merrion Way
Leeds LS2 8PA
ROYAUME-UNI

Date of mailing (day/month/year)
04 juillet 2001 (04.07.01)

Applicant's or agent's file reference
CTV/P45133WO

IMPORTANT NOTIFICATION

International application No.
PCT/GB00/00521

International filing date (day/month/year)
17 février 2000 (17.02.00)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

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State of Nationality: GB
State of Residence: GB
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Facsimile No.:
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

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Authorized officer
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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

HARRISON GODDARD FOOTE
Belgrave Hall
Belgrave Street
Leeds LS2 8DD
ROYAUME-UNI

Date of mailing (day/month/year)
04 December 2001 (04.12.01)

Applicant's or agent's file reference
CTV/P45133WO

IMPORTANT NOTIFICATION

International application No.
PCT/GB00/00521

International filing date (day/month/year)
17 February 2000 (17.02.00)

1. The following indications appeared on record concerning:

[ ] the applicant [ ] the inventor [X] the agent [ ] the common representative

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3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

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Authorized officer
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PATENT COOPERATION TREATY

PCT

10.MAY2001 05:12:25

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
CTV/P45133WO		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/00521	17/02/2000	17/02/1999
International Patent Classification (IPC) or national classification and IPC B01J19/18		
Applicant UNIVERSITY OF NEWCASTLE et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 12 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
15/09/2000	08.05.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Buesing, G Telephone No. +49 89 2399 8356

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/00521

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1,9,10,12-17	as originally filed			
2-8,11	as received on	20/03/2001	with letter of	19/03/2001

Claims, No.:

10	as originally filed			
1-9,11-33	as received on	20/03/2001	with letter of	19/03/2001

Drawings, sheets:

1/5-5/5	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/00521

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1 - 9, 11 - 33
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1 - 9, 11 - 33
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1 - 9, 11 - 33
	No:	Claims	

2. Citations and explanations
   see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

INTERNATIONAL PRELIMINARY EXAMINATION REPORT - SEPARATE SHEET

International application No. PCT/GB00/00521

Section V:

1. The invention relates to a spinning disc reactor and in particular considers feed means for supplying reactant to a rotatable surface. The problem to be solved was to provide improved control over the supply of the reactant to a spinning surface. This problem has been solved by the provision of an undercut trough into which the reactant is supplied and wherein, upon rotation of the surface, an annular film is formed. Overflow from the film onto the spinning surface results in the formation of a thin film on the rotating surface.

2. There is no prior art that discloses a similar supply of reactant to a rotating surface. Consequently, the claimed subject-matter is novel. It is also inventive because the ordinarily skilled worker will get no incentive from the available prior art documents for designing the reactor as now claimed.

Section VIII:

1. It is observed that claim 10 is missing in the amended set of claims. Amended page 19 starts with a half line which is equivalent to the last portion of original claim 11. It appears that it was intended to include an amended claim 10 similar to original claim 11.

These publications therefore disclose the use of spinning disc technology for heating and mass transfer in inert and reactive systems.

GB 9903474.6 (University of Newcastle), from which the present application claims priority and the disclosure of which is hereby incorporated into the present application by reference, describes the use of RSORT in the conversion of a fluid phase substrate by dynamic heterogeneous contact with an agent. In this application, it is described how it has surprisingly been found that spinning disc technology may be further adapted to apply process intensification methods not only within the fields of heat and mass transfer but also within the field of heterogeneous contacting. Furthermore, it is described how it has surprisingly been found that the quality of the product obtained is of higher quality than that obtained by conventional processing having, for example, a higher purity or, in polymers, a narrower molecular distribution.

In addition to this, spinning disc technology can be used to obtain products not readily obtainable by other technology.

According to the present invention, there is provided a reactor apparatus including a support element adapted to be rotatable about an axis, the support element having a surface, feed means for supplying at least one reactant to the surface of the support element and collector means for collecting product from the surface of the support element, characterised in that the surface includes an undercut trough into which the at least one reactant is directly supplied by the feed means when the reactor apparatus is in use, and in that, upon rotation of the support element, the at least one reactant forms a generally annular film within the at least one undercut trough and passes therefrom across the surface of the support element.

It is to be understood that the term "reactant" is not limited to substances which are intended to undergo chemical reaction on the surface of the support element, but also includes substances which are intended to undergo physical or other processes such as mixing or heating. Similarly, the term "product" is intended to denote the substance or substances which are collected from the surface of the support element, whether these have undergone chemical or physical processing or both. In addition, although it is envisaged that most reactants and products will be in the liquid phase, the apparatus can be used with any suitable fluid phase reactants and products, including combinations of liquid, solid and gaseous reactants and products. For example, solid phase substances in substantially free-flowing particulate form can have macroscopic fluid flow properties.

The depth of the trough may be selected in accordance with reaction requirements. For example, for photochemical reactions in which UV light is shone onto the reactant, it is preferred for the trough to be relatively shallow, for example having a depth of the same order of magnitude or within one order of magnitude as the expected thickness of a film of reactant formed across the surface of the support element when rotating at an appropriate speed.

An RSORT apparatus (commonly known as a spinning disc reactor) generally includes within a conversion chamber a rotating surface or an assembly of a plurality of these which is rotated about an axis to effect transfer of one or more reactants from the axis preferably radially across the rotating surface.

An RSORT apparatus as hereinbefore defined comprising a rotating surface as hereinbefore defined has a number of advantageous constructional features according to the present invention.

The axis of rotation of the rotating surface or support member may be substantially vertical, in which case gravity tends to pull reactants downwardly with respect to the surface or support member. This may be advantageous with less viscous reactants. Alternatively, the axis of rotation may be generally horizontal, which can achieve improved mixing of reactants provided that these are appropriately retained on the surface of the support member.

Any suitable feed means may be provided to feed the at least one reactant onto the rotating surface. For example, the feed means may comprise a feed distributor in the form of a "shower head", a "necklace" of outlets or a simple, preferably adjustable, single point introduction such as a "hose-pipe type" feed means. Preferably, the feed means comprises a feed distributor having a plurality of uniformly spaced outlets for the at least one reactant on to the rotating surface as hereinbefore defined. The feed means may also include means for applying UV, IR, X-ray, RF, microwave or other types of electromagnetic radiation or energy, including magnetic and electric fields, to the reactants as they are fed to the trough, or may include means for applying vibration, such as ultrasonic vibration, or heat.

The feed means may be provided at any suitable position with respect to the rotating surface which allows feed of the reactant. For example, the feed means may be

axially aligned with the rotating surface for axial feed. Alternatively, the feed means may be positioned such that the feed is spaced from the axis of the rotating surface. Such a position may lead to more turbulence and an enhanced mixing effect.

In one embodiment, feed means may comprise a single feed to the trough which is preferably situated on or co-axial with the axis of rotation of the rotating surface. In this embodiment, reactant flows form the feed outlet into the trough and is subsequently spread out of the trough on to the rotating surface by centrifugal force. In a preferred embodiment, the rotating element as hereinbefore defined comprises a trough situated on the axis of rotation.

The trough as hereinbefore defined may be of any suitable shape such as continuous or annular. For example it may have a continuous concave surface comprising part of a sphere, such as a hemispherical surface, or it may have an inner surface joined to the rotating surface by at least one connection wall or at least two, in the case where the trough is annular. The inner surface and connection wall may be of any form which allows the function of a trough to be fulfilled. For example the inner surface may be parallel to the rotating surface or concave or convex. The connection wall may comprise a single circular or ovoid wall or a plurality of straight walls. The walls may diverge or converge towards the rotating surface.

Preferably, a single circular wall is provided which converges towards the rotating surface to form an undercut trough. This shape generates a reservoir which enhances a circumferential distribution of the reactant flow. Alternative means for forming an undercut trough are also envisaged. For example, where the trough is generally annular in shape, an outer wall may be provided as above, and an inner wall having any suitable shape may serve to define an inner edge to the trough. The undercut portion of the trough should generally be provided as an outer wall so as to help prevent uncontrolled egress of reactant from the trough to the surface under the influence of centrifugal force as the support element is rotated.

Advantageously, a matrix may be provided in the trough so as to help reactant present in the trough to rotate with the support element, thereby helping to achieve substantially uniform flow from the trough across the surface. The matrix may be in the form of a plug of fibrous mesh, such as metal or plastics wool, or may take the form of a plurality of projections which are secured to an inner surface of the trough. Other matrix means will be apparent to the skilled reader. In some

embodiments, the matrix is manufactured of a material which is inert with respect to the at least one reactant or the product and which is not significantly affected by temperature and other variable process conditions. Alternatively, the matrix may be made of a material which does interact with the at least one reactant or the product, such as a heterogeneous catalyst (e.g. nickel, palladium or platinum or any suitable metal or alloy or compound thereof). Where the matrix is made out of an electrically conductive material, it may be possible to supply an electric current therethrough and thus to provide heating means for heating the at least one reactant within the trough.

In a further embodiment, there may be provided a plurality of feeds adapted selectively to supply one or more reactants to a plurality of troughs formed in the surface. For example, where the support element is generally disc-like and has a substantially central axis of rotation, there may be provided a first central trough centred on the axis of rotation and feed means for supplying at least one reactant to the first trough, and at least one further trough, preferably also centred on the axis of rotation and having an annular configuration, the at least one further trough being provided with feed means for supplying a second reactant, which may be the same as or different from the first reactant, to the at least one further trough. It will be apparent to the skilled reader that a plurality of troughs may be provided in a similar manner on support elements with shapes other than generally disc-like.

By providing a plurality of troughs and feeds, a sequence of reactions can be performed across the surface of the support element. For example, two reactants may be supplied to the first trough in which some mixing and reaction will take place. As the support element rotates, the reactants will spread from the first trough to the surface of the support element, where further reaction and mixing takes place, and thence into a second annular trough concentric with the first trough. A third reactant may then be supplied to the second trough, and further mixing and reaction will take place as the third reactant and the two initial reactants and any associated product are spread from the second trough onto the surface of the support element for further mixing and reaction. Because the direction of travel of the reactants and products is outwards from the axis of rotation, a controlled series of reactions can be carried out across the surface of the support member.

In some embodiments, one of the reactants may be a liquid phase component and another may be a gaseous phase component. In these embodiment, the rotating support member is advantageously contained within a vessel so as to allow the

concentration of the gaseous phase component in the vicinity of the surface to be controlled. The liquid component may be fed to the surface of the disc as described above, and the gaseous component supplied to the vessel. A rotary impeller or fan or similar device may be mounted close to the rotating surface and driven so as to suck the gaseous phase component from a region surrounding the periphery of the rotating surface towards the centre of the rotating surface while the liquid phase component travels from the centre of the surface towards its periphery due to the rotation of the rotating surface. Where, for example, the support element is a disc, the impeller or fan may take the form of a generally disc shaped structure mounted coaxially with the support element and close thereto. A surface of the impeller or fan facing the rotating surface of the support element may be provided with blades or vanes such that rotation of the impeller or fan serves to suck the gaseous phase component from a periphery of the surface and the impeller or fan towards the centre of the surface. By providing a counter-current flow of the gaseous and liquid phase components, heat or mass transfer between the components is much improved, since the concentration of unreacted liquid phase reactant is lowest at the periphery of the disc, and therefore benefits from a high concentration of the gaseous phase component so as to ensure full reaction.

Any suitable collection means may be provided for collection of the product as it leaves the rotating surface at its periphery. For example, there may be provided a receptacle in the form of a bowl or trough at least partially surrounding the rotating element or other fixed part of the apparatus. The collection means may additionally comprise a deflector positioned around the periphery of the rotating surface to deflect product into the collection means. The deflector is preferably positioned at an acute angle to the rotating surface.

The components of the collection means, such as the bowl or trough or deflector, may be coated or otherwise provided with a heterogeneous catalyst appropriate to the reactants being reacted on the support element, or may even consist entirely of a material which acts as a heterogeneous catalyst. Furthermore, the components of the collection means may be heated or cooled to a predetermined temperature so as to enable control over reaction parameters, for example by serving to halt the reaction between reactants as these leave the surface in the form of product. Feed means for supplying a reactant to the product leaving the surface may also be provided. For example, there may be provided feed means for feeding a quenching medium to product in the collection means so as to halt chemical or other reactions between

reactants when these have left the surface.

The collection means may further comprise outlet means of any suitable form. For example, there may be a single collection trough running around the periphery of the disc or a collection bowl partially surrounding the rotating element.

Outlet means may also be provided in the collection means and these may take the form of apertures of any size and form situated at any suitable position of the collection means to allow egress of the product. In one preferred embodiment, the outlet means are situated to allow vertical egress of the substrate in use.

Alternatively, the collection means may comprise an outer wall provided at the periphery of the support element so as to prevent product from being thrown from the surface, and at least one pitot tube which extends into the product which is restrained at the periphery of the support element by the outer wall. The outer wall may converge generally towards the axis of rotation of the support member so as better to retain product while the support element is undergoing rotation, although other wall configurations, such as generally parallel to or divergent from the axis of rotation may also be useful.

Embodiments of the present invention may include multiple support elements, which may share a common axis of rotation and which may be mounted on a single rotatable shaft, or which may be provided with individual rotatable shafts. The collection means associated with any given support element may be connected to the feed means associated with any other given support element so as to link a number of support elements in series or parallel. In this way, a reaction may be conducted across a number of support elements in series or parallel. The collection means of a first support member may be directly connected to the feed means of a second support member, or may be connected by way of a processing unit such as a pump, extruder, heater or heat exchanger or any other appropriate device. This is especially useful when dealing with viscous products, such as those which are obtained in polymerisation reactions, since the viscous product of a first support element may be processed so as to acquire more favourable physical characteristics before being used as the reactant feed for a second support element.

For example, where the collection means comprises an outer wall on the surface of the support element as described above, a number of support elements may be

coaxially mounted on a single rotatable shaft so as to form a stack of support elements. A reactant feed is led to the trough of a first support element, and a collector in the form of a pitot tube has its tip located near the surface of the first support element in the vicinity of the wall so as to take up product from this region. An end of the pitot tube remote from the tip is led to the trough of a second support element so as to allow the product of the first support element to serve as the reactant for the second support element, thereby allowing a number of reactions to take place in series. Alternatively, a number of parallel feeds may supply the same at least one reactant simultaneously to the troughs of a number of support elements and a number of parallel pitot tube collectors may gather product from a peripheral region of each support element, thereby allowing a reaction to take place across a number of support elements in parallel.

It is also envisaged that product collected from the periphery of a support element may be recycled as feed for that support element. This is useful for processes requiring an extended contact time for the reactants. The product may be fully or only partially recycled, depending on requirements.

Reference herein to a rotating surface is to any continuous or discrete planar or three dimensional surface or assembly which rotates approximately or truly about an axis, and preferably is reference to an approximate or true rotating surface of revolution. An approximate rotating surface of revolution may comprise an asymmetric axis and/or deviation in the surface body and/or circumference creating an axially or radially undulating surface of revolution. A discrete surface may be in the form of a mesh, grid, corrugated surface and the like.

Reference herein to a substantially radially outward flowing film as hereinbefore defined is to any fluid film which may be created by dynamic contact of the fluid phase reactant and the rotating surface as hereinbefore defined, suitably the fluid phase reactant is contacted with the rotating surface at any one or more surface locations and caused to flow outwardly by the action of centrifugal force. A film may be a continuous annulus or may be a non-continuous arc at any radial location. The substrate may provide a plurality of films in dynamic contact with a rotating surface as hereinbefore defined.

For example processes requiring extended contact time may be carried out in continuous manner with use of a recycle of fluid exiting at the periphery of the

supplied to a region within the innermost wall on one of the support elements. Upon rotation of the support elements, the reactant will tend to move along an interior surface of the divergent wall towards a region within the next wall on the opposed support element, and thence onto an interior surface of the said next wall back towards the first support element. The reactant may continue to move back and forth between the support members so as to progress in a zig-zag manner in a generally radial direction away from the axis of rotation along the interior surfaces of the intermeshed walls towards an outer collection point as described above. In this way, a compact reactor with a high surface area is achieved, the surface consisting of the interior surfaces of all the concentric walls. The support elements may rotate together in a given direction, or may rotate at different speeds in the same direction, or may rotate at the same speed or at different speeds in opposed directions.

A rotating surface of any shape and surface formation as hereinbefore defined may be provided with surface features which serve to promote the desired process. For example, the surface may be micro or macro profiled, micro or macro porous, non stick, for example may have a release coating, may be continuous or discontinuous and may comprise elements such as mesh, for example woven mesh, reticulate foam, pellets, cloth, pins or wires, for enhanced surface area, enhanced or reduced friction effect, enhanced or reduced laminar flow, shear mixing of recirculation flow in axial direction and the like.

In one preferred embodiment, mixing characteristics of the rotating surface are enhanced by the above features or the like provided on or in the rotating surface. These may be provided in any suitable regular or random arrangement of grids, concentric rings, spider web or like patterns which may be suitable for a given application.

Alternatively or additionally to any other surface feature, radially spaced pins in the form of circles or segments of circles may be provided.

In another preferred embodiment, a porous surface coating is provided, which aids processing of certain reactants. Such a coating may be provided in combination with any other of the aforementioned surface features.

Surface features in the form of grooves may be concentric or may be of any desired

CLAIMS:

1. A reactor apparatus including a support element (3) adapted to be rotatable about an axis (6), the support element (3) having a surface (5), feed means (4) for supplying at least one reactant (15) to the surface (5) of the support element (3) and collector means for collecting product (19) from the surface (5) of the support element (3), characterised in that the surface (5) includes an undercut trough (13,14) into which the at least one reactant (15) is directly supplied by the feed means (4) when the reactor apparatus is in use, and in that, upon rotation of the support element (3), the at least one reactant (15) forms a generally annular film (16) within the at least one undercut trough (13,14) and passes therefrom across the surface (5) of the support element (3).

2. A reactor as claimed in claim 1, wherein the axis (6) is substantially parallel to a direction of action of terrestrial gravity.

3. A reactor as claimed in claim 1, wherein the axis (6) is inclined with respect to a direction of action of terrestrial gravity.

4. A reactor as claimed in claim 1 or 3, wherein the axis (6) is substantially perpendicular to a direction of action of terrestrial gravity.

5. A reactor as claimed in any preceding claim, wherein the trough (13,14) is centrally located in the region of the axis (6).

6. A reactor as claimed in any preceding claim, wherein the trough (13,14) is in the form of an annulus.

7. A reactor as claimed in any preceding claim, wherein the trough (13,14) is centred about the axis (6).

8. A reactor as claimed in any one of claims 1 to 6, wherein the trough (13,14) is not centred on the axis.

9. A reactor as claimed in any preceding claim, wherein a plurality of troughs (13,14) is provided in the surface (5).

AMENDED SHEET

with it a feed means (4).

11. A reactor as claimed in any preceding claim, wherein the trough (13,14) is provided with a matrix which serves to assist reactant (15) in the trough (13,14) to rotate with the support element (3) when this is rotated.

12. A reactor as claimed in claim 11, wherein the matrix comprises a fibrous mesh.

13. A reactor as claimed in claim 12, wherein the fibrous mesh is made of a metallic material.

14. A reactor as claimed in claim 12 or 13, wherein the fibrous mesh includes a catalytic material.

15. A reactor as claimed in any preceding claim, wherein the collector means includes a receptacle (7) in the form of a bowl or trough at least partially surrounding the support element (3).

16. A reactor as claimed in any preceding claim, wherein the collector means includes a deflector positioned about a periphery of the support element (3), against which product (19) is thrown from an edge region of the surface (5) when the support element (3) is rotating at an appropriate speed.

17. A reactor as claimed in any preceding claim, wherein the collector means is coated or otherwise provided with a catalytic material.

18. A reactor as claimed in any preceding claim, wherein the collector means includes means for heating or cooling product (19) in the collector means to a predetermined temperature.

19. A reactor as claimed in any preceding claim, wherein the collector means is provided with feed means for adding a reactant to product (19) collected therein.

20. A reactor as claimed in any preceding claim, wherein the collector means comprises a wall (18) disposed on a periphery of the support element (3) and extending from the surface (5).

21. A reactor as claimed in claim 20, wherein the collector means further comprises a pitot tube (20) which extends close to the surface (5) in the region of the wall (18) and which serves to remove product (19) from this region when the support element (3) is rotated.

22. A reactor as claimed in any preceding claim, wherein the collector means is adapted at least partially to recycle collected product (19) to the trough (13,14) as feed reactant.

23. A reactor as claimed in any preceding claim, wherein the trough (13,14) is coated or otherwise provided with a catalytic material.

24. A reactor as claimed in any preceding claim, including a plurality of support elements (3).

25. A reactor as claimed in claim 24, wherein the plurality of support elements (3) is mounted on a single axis of rotation (6).

26. A reactor as claimed in claim 24, wherein the plurality of support elements (3) is mounted on a plurality of axes of rotation (6).

27. A reactor as claimed in any one of claims 24 to 26, wherein product (19) collected from a first support member (3) is used as feed for a second support member (3).

28. A reactor as claimed in any one of claims 24 to 26, wherein feed means (4) connected in parallel are used to supply reactant (15) to each support element (3) and in which collector means (20) connected in parallel are used to collect product (19) from each support element (3).

29. A reactor as claimed in claim 27, wherein a processing unit (22) is provided between the collector means (21) of the first support member (3) and the feed means (4) of the second support member (3).

30. A reactor as claimed in claim 29, wherein the processing unit (22) is a pump, an extruder, a heater or a heat exchanger.

31. A reactor as claimed in any preceding claim, wherein the feed means (4) includes means for applying electromagnetic radiation or energy to the reactant (15).

32. A reactor as claimed in any preceding claim, further including means for applying vibration to the support member (3).

33. A reactor as claimed in any preceding claim, wherein there is further provided a rotary impeller or fan (70) mounted close to the surface (5) and operable to generate a gaseous flow from a periphery of the surface (5) towards a central region thereof, this flow being counter-current to a flow of reactant (15) on the surface (5).

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
CTV/P45133WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 00521	17/02/2000	17/02/1999
Applicant		
UNIVERSITY OF NEWCASTLE et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PC[redacted] 00/00521

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01J19/18 B01J19/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 549 998 A (PORTER JOHN E, RAMSHAW COLIN) 29 October 1985 (1985-10-29) column 3, line 12 - line 61 column 4, line 46 -column 5, line 8 figures 1-3	1,2,6, 10, 12-14, 16,24,25
A	US 4 627 803 A (UMETSU JUNICHI) 9 December 1986 (1986-12-09) the whole document	1,2,5,7, 23
A	US 4 311 570 A (COWEN GEOFFREY, NORTON-BERRY PHILIP, STEEL MARGARET L) 19 January 1982 (1982-01-19) column 9, line 7 -column 10, line 33 claims 1-9; figures 1,2	1,12,13, 15,16, 31,33

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 August 2000	10/08/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Vlassis, M

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PC[redacted] 00/00521

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 020 055 A (ICI PLC) 10 December 1980 (1980-12-10) page 10, line 15 -page 15, line 9 page 20, line 1 -page 21, line 12 figures 1-4	1-4,16, 24
A	EP 0 810 633 A (TOKYO ELECTRON LTD) 3 December 1997 (1997-12-03) page 5, line 17 - line 59 page 7, line 22 - line 28 page 8, line 14 - line 18 figures 3,8	1,2,16, 17,33

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PC[redacted] 00/00521

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 August 2000 (24.08.2000)

PCT

(10) International Publication Number
WO 00/48729 A3

(51) International Patent Classification[7]: B01J 19/18, 19/12

(21) International Application Number: PCT/GB00/00521

(22) International Filing Date: 17 February 2000 (17.02.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9903474.6 17 February 1999 (17.02.1999) GB

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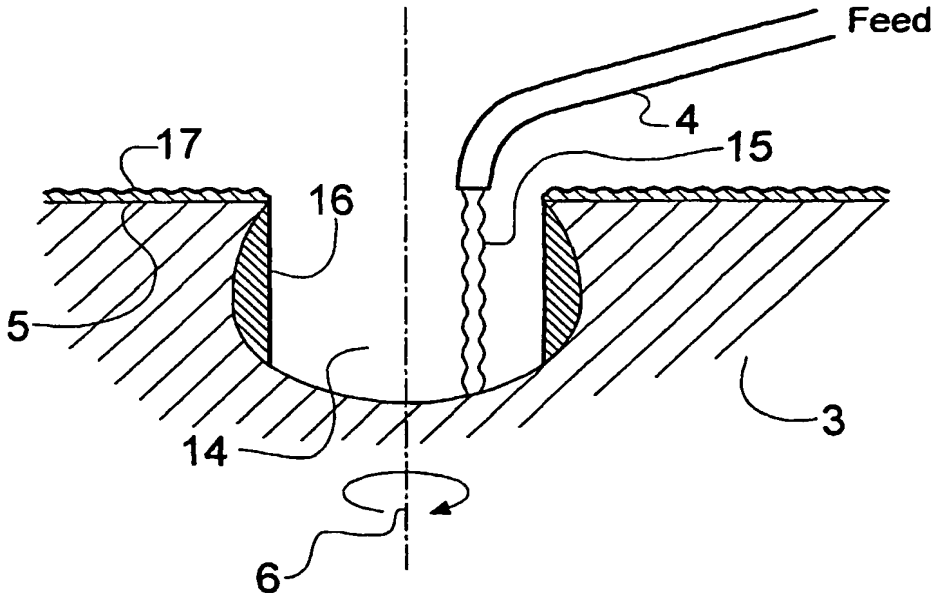
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: ROTATING SURFACE OF REVOLUTION REACTOR WITH FEED AND COLLECTION MECHANISMS



(57) Abstract: A reactor including a rotatable disc (3) having a trough (13) in an upper surface (5) thereof. Reactant (15) is supplied to the trough (13) by way of a feed (4), the disc (3) is rotated at high speed, and the reactant (15) spills out of the trough (13) so as to form a film (17) on the surface (5). As the reactant (15) traverses the surface (5) of the disc (3), it undergoes chemical or physical processes before being thrown from the periphery of the disc (3) into collector means (7).

WO 00/48729 A3

(88) Date of publication of the international search report:
7 December 2000

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

These publications therefore disclose the use of spinning disc technology for heating and mass transfer in inert and reactive systems.

GB 9903474.6 (University of Newcastle), from which the present application claims priority and the disclosure of which is hereby incorporated into the present application by reference, describes the use of RSORT in the conversion of a fluid phase substrate by dynamic heterogeneous contact with an agent. In this application, it is described how it has surprisingly been found that spinning disc technology may be further adapted to apply process intensification methods not only within the fields of heat and mass transfer but also within the field of heterogeneous contacting. Furthermore, it is described how it has surprisingly been found that the quality of the product obtained is of higher quality than that obtained by conventional processing having, for example, a higher purity or, in polymers, a narrower molecular distribution.

In addition to this, spinning disc technology can be used to obtain products not readily obtainable by other technology.

According to the present invention, there is provided a reactor apparatus including a support element adapted to be rotatable about an axis, the support element having generally opposed first and second surfaces, feed means for supplying at least one reactant to the first surface of the support element and collector means for collecting product from the first surface of the support element, characterised in that the first surface includes a trough into which the at least one reactant is supplied by the feed means.

It is to be understood that the term "reactant" is not limited to substances which are intended to undergo chemical reaction on the surface of the support element, but also includes substances which are intended to undergo physical or other processes such as mixing or heating. Similarly, the term "product" is intended to denote the substance or substances which are collected from the first surface of the support element, whether these have undergone chemical or physical processing or both. In addition, although it is envisaged that most reactants and products will be in the liquid phase, the apparatus can be used with any suitable fluid phase reactants and products, including combinations of liquid, solid and gaseous reactants and products. For example, solid phase substances in substantially free-flowing particulate form can have macroscopic fluid flow properties.

The depth of the trough may be selected in accordance with reaction requirements. For example, for photochemical reactions in which UV light is shone onto the reactant, it is preferred for the trough to be relatively shallow, for example having a depth of the same order of magnitude or within one order of magnitude as the expected thickness of a film of reactant formed across the first surface of the support element when rotating at an appropriate speed.

An RSORT apparatus (commonly known as a spinning disc reactor) generally includes within a conversion chamber a rotating surface or an assembly of a plurality of these which is rotated about an axis to effect transfer of one or more reactants from the axis preferably radially across the rotating surface.

An RSORT apparatus as hereinbefore defined comprising a rotating surface as hereinbefore defined has a number of advantageous constructional features according to the present invention.

The axis of rotation of the rotating surface or support member may be substantially vertical, in which case gravity tends to pull reactants downwardly with respect to the surface or support member. This may be advantageous with less viscous reactants. Alternatively, the axis of rotation may be generally horizontal, which can achieve improved mixing of reactants provided that these are appropriately retained on the first surface of the support member.

Any suitable feed means may be provided to feed the at least one reactant onto the rotating surface. For example, the feed means may comprise a feed distributor in the form of a "shower head", a "necklace" of outlets or a simple, preferably adjustable, single point introduction such as a "hose-pipe type" feed means. Preferably, the feed means comprises a feed distributor having a plurality of uniformly spaced outlets for the at least one reactant on to the rotating surface as hereinbefore defined. The feed means may also include means for applying UV, IR, X-ray, RF, microwave or other types of electromagnetic radiation or energy, including magnetic and electric fields, to the reactants as they are fed to the trough, or may include means for applying vibration, such as ultrasonic vibration, or heat.

The feed means may be provided at any suitable position with respect to the rotating surface which allows feed of the reactant. For example, the feed means may be

axially aligned with the rotating surface for axial feed. Alternatively, the feed means may be positioned such that the feed is spaced from the axis of the rotating surface. Such a position may lead to more turbulence and an enhanced mixing effect.

In one embodiment, feed means may comprise a single feed to the trough which is preferably situated on or co-axial with the axis of rotation of the rotating surface. In this embodiment, reactant flows form the feed outlet into the trough and is subsequently spread out of the trough on to the rotating surface by centrifugal force. In a preferred embodiment, the rotating element as hereinbefore defined comprises a trough situated on the axis of rotation.

The trough as hereinbefore defined may be of any suitable shape such as continuous or annular. For example it may have a continuous concave surface comprising part of a sphere, such as a hemispherical surface, or it may have an inner surface joined to the rotating surface by at least one connection wall or at least two, in the case where the trough is annular. The inner surface and connection wall may be of any form which allows the function of a trough to be fulfilled. For example the inner surface may be parallel to the rotating surface or concave or convex. The connection wall may comprise a single circular or ovoid wall or a plurality of straight walls. The walls may diverge or converge towards the rotating surface.

Preferably, a single circular wall is provided which converges towards the rotating surface to form an undercut trough. This shape generates a reservoir which enhances a circumferential distribution of the reactant flow. Alternative means for forming an undercut trough are also envisaged. For example, where the trough is generally annular in shape, an outer wall may be provided as above, and an inner wall having any suitable shape may serve to define an inner edge to the trough. The undercut portion of the trough should generally be provided as an outer wall so as to help prevent uncontrolled egress of reactant from the trough to the first surface under the influence of centrifugal force as the support element is rotated.

Advantageously, a matrix may be provided in the trough so as to help reactant present in the trough to rotate with the support element, thereby helping to achieve substantially uniform flow from the trough across the first surface. The matrix may be in the form of a plug of fibrous mesh, such as metal or plastics wool, or may take the form of a plurality of projections which are secured to an inner surface of the trough. Other matrix means will be apparent to the skilled reader. In some

embodiments, the matrix is manufactured of a material which is inert with respect to the at least one reactant or the product and which is not significantly affected by temperature and other variable process conditions. Alternatively, the matrix may be made of a material which does interact with the at least one reactant or the product, such as a heterogeneous catalyst (e.g. nickel, palladium or platinum or any suitable metal or alloy or compound thereof). Where the matrix is made out of an electrically conductive material, it may be possible to supply an electric current therethrough and thus to provide heating means for heating the at least one reactant within the trough.

In a further embodiment, there may be provided a plurality of feeds adapted selectively to supply one or more reactants to a plurality of troughs formed in the first surface. For example, where the support element is generally disc-like and has a substantially central axis of rotation, there may be provided a first central trough centred on the axis of rotation and feed means for supplying at least one reactant to the first trough, and at least one further trough, preferably also centred on the axis of rotation and having an annular configuration, the at least one further trough being provided with feed means for supplying a second reactant, which may be the same as or different from the first reactant, to the at least one further trough. It will be apparent to the skilled reader that a plurality of troughs may be provided in a similar manner on support elements with shapes other than generally disc-like.

By providing a plurality of troughs and feeds, a sequence of reactions can be performed across the first surface of the support element. For example, two reactants may be supplied to the first trough in which some mixing and reaction will take place. As the support element rotates, the reactants will spread from the first trough to the first surface of the support element, where further reaction and mixing takes place, and thence into a second annular trough concentric with the first trough. A third reactant may then be supplied to the second trough, and further mixing and reaction will take place as the third reactant and the two initial reactants and any associated product are spread from the second trough onto the first surface of the support element for further mixing and reaction. Because the direction of travel of the reactants and products is outwards from the axis of rotation, a controlled series of reactions can be carried out across the first surface of the support member.

In some embodiments, one of the reactants may be a liquid phase component and another may be a gaseous phase component. In these embodiment, the rotating support member is advantageously contained within a vessel so as to allow the

concentration of the gaseous phase component in the vicinity of the surface to be controlled. The liquid component may be fed to the surface of the disc as described above, and the gaseous component supplied to the vessel. A rotary impeller or fan or similar device may be mounted close to the rotating surface and driven so as to suck the gaseous phase component from a region surrounding the periphery of the rotating surface towards the centre of the rotating surface while the liquid phase component travels from the centre of the surface towards its periphery due to the rotation of the rotating surface. Where, for example, the support element is a disc, the impeller or fan may take the form of a generally disc shaped structure mounted coaxially with the support element and close thereto. A surface of the impeller or fan facing the rotating surface of the support element may be provided with blades or vanes such that rotation of the impeller or fan serves to suck the gaseous phase component from a periphery of the surface and the impeller or fan towards the centre of the surface. By providing a counter-current flow of the gaseous and liquid phase components, heat or mass transfer between the components is much improved, since the concentration of unreacted liquid phase reactant is lowest at the periphery of the disc, and therefore benefits from a high concentration of the gaseous phase component so as to ensure full reaction.

Any suitable collection means may be provided for collection of the product as it leaves the rotating surface at its periphery. For example, there may be provided a receptacle in the form of a bowl or trough at least partially surrounding the rotating element or other fixed part of the apparatus. The collection means may additionally comprise a deflector positioned around the periphery of the rotating surface to deflect product into the collection means. The deflector is preferably positioned at an acute angle to the rotating surface.

The components of the collection means, such as the bowl or trough or deflector, may be coated or otherwise provided with a heterogeneous catalyst appropriate to the reactants being reacted on the support element, or may even consist entirely of a material which acts as a heterogeneous catalyst. Furthermore, the components of the collection means may be heated or cooled to a predetermined temperature so as to enable control over reaction parameters, for example by serving to halt the reaction between reactants as these leave the first surface in the form of product. Feed means for supplying a reactant to the product leaving the first surface may also be provided. For example, there may be provided feed means for feeding a quenching medium to product in the collection means so as to halt chemical or other reactions between

reactants when these have left the first surface.

The collection means may further comprise outlet means of any suitable form. For example, there may be a single collection trough running around the periphery of the disc or a collection bowl partially surrounding the rotating element.

Outlet means may also be provided in the collection means and these may take the form of apertures of any size and form situated at any suitable position of the collection means to allow egress of the product. In one preferred embodiment, the outlet means are situated to allow vertical egress of the substrate in use.

Alternatively, the collection means may comprise an outer wall provided at the periphery of the support element so as to prevent product from being thrown from the first surface, and at least one pitot tube which extends into the product which is restrained at the periphery of the support element by the outer wall. The outer wall may converge generally towards the axis of rotation of the support member so as better to retain product while the support element is undergoing rotation, although other wall configurations, such as generally parallel to or divergent from the axis of rotation may also be useful.

Embodiments of the present invention may include multiple support elements, which may share a common axis of rotation and which may be mounted on a single rotatable shaft, or which may be provided with individual rotatable shafts. The collection means associated with any given support element may be connected to the feed means associated with any other given support element so as to link a number of support elements in series or parallel. In this way, a reaction may be conducted across a number of support elements in series or parallel. The collection means of a first support member may be directly connected to the feed means of a second support member, or may be connected by way of a processing unit such as a pump, extruder, heater or heat exchanger or any other appropriate device. This is especially useful when dealing with viscous products, such as those which are obtained in polymerisation reactions, since the viscous product of a first support element may be processed so as to acquire more favourable physical characteristics before being used as the reactant feed for a second support element.

For example, where the collection means comprises an outer wall on the first surface of the support element as described above, a number of support elements may be

coaxially mounted on a single rotatable shaft so as to form a stack of support elements. A reactant feed is led to the trough of a first support element, and a collector in the form of a pitot tube has its tip located near the first surface of the first support element in the vicinity of the wall so as to take up product from this region. An end of the pitot tube remote from the tip is led to the trough of a second support element so as to allow the product of the first support element to serve as the reactant for the second support element, thereby allowing a number of reactions to take place in series. Alternatively, a number of parallel feeds may supply the same at least one reactant simultaneously to the troughs of a number of support elements and a number of parallel pitot tube collectors may gather product from a peripheral region of each support element, thereby allowing a reaction to take place across a number of support elements in parallel.

It is also envisaged that product collected from the periphery of a support element may be recycled as feed for that support element. This is useful for processes requiring an extended contact time for the reactants. The product may be fully or only partially recycled, depending on requirements.

Reference herein to a rotating surface is to any continuous or discrete planar or three dimensional surface or assembly which rotates approximately or truly about an axis, and preferably is reference to an approximate or true rotating surface of revolution. An approximate rotating surface of revolution may comprise an asymmetric axis and/or deviation in the surface body and/or circumference creating an axially or radially undulating surface of revolution. A discrete surface may be in the form of a mesh, grid, corrugated surface and the like.

Reference herein to a substantially radially outward flowing film as hereinbefore defined is to any fluid film which may be created by dynamic contact of the fluid phase reactant and the rotating surface as hereinbefore defined, suitably the fluid phase reactant is contacted with the rotating surface at any one or more surface locations and caused to flow outwardly by the action of centrifugal force. A film may be a continuous annulus or may be a non-continuous arc at any radial location. The substrate may provide a plurality of films in dynamic contact with a rotating surface as hereinbefore defined.

For example processes requiring extended contact time may be carried out in continuous manner with use of a recycle of fluid exiting at the periphery of the

supplied to a region within the innermost wall on one of the support elements. Upon rotation of the support elements, the reactant will tend to move along an interior surface of the divergent wall towards a region within the next wall on the opposed support element, and thence onto an interior surface of the said next wall back towards the first support element. The reactant may continue to move back and forth between the support members so as to progress in a zig-zag manner in a generally radial direction away from the axis of rotation along the interior surfaces of the intermeshed walls towards an outer collection point as described above. In this way, a compact reactor with a high first surface area is achieved, the first surface consisting of the interior surfaces of all the concentric walls. The support elements may rotate together in a given direction, or may rotate at different speeds in the same direction, or may rotate at the same speed or at different speeds in opposed directions.

A rotating surface of any shape and surface formation as hereinbefore defined may be provided with surface features which serve to promote the desired process. For example, the surface may be micro or macro profiled, micro or macro porous, non stick, for example may have a release coating, may be continuous or discontinuous and may comprise elements such as mesh, for example woven mesh, reticulate foam, pellets, cloth, pins or wires, for enhanced surface area, enhanced or reduced friction effect, enhanced or reduced laminar flow, shear mixing of recirculation flow in axial direction and the like.

In one preferred embodiment, mixing characteristics of the rotating surface are enhanced by the above features or the like provided on or in the rotating surface. These may be provided in any suitable regular or random arrangement of grids, concentric rings, spider web or like patterns which may be suitable for a given application.

Alternatively or additionally to any other surface feature, radially spaced pins in the form of circles or segments of circles may be provided.

In another preferred embodiment, a porous surface coating is provided, which aids processing of certain reactants. Such a coating may be provided in combination with any other of the aforementioned surface features.

Surface features in the form of grooves may be concentric or may be of any desired

CLAIMS:

1. A reactor apparatus including a support element adapted to be rotatable about an axis, the support element having generally opposed first and second surfaces, feed means for supplying at least one reactant to the first surface of the support element and collector means for collecting product from the first surface of the support element, characterised in that the first surface includes a trough into which the at least one reactant is supplied by the feed means.

2. A reactor as claimed in claim 1, wherein the axis is substantially parallel to a direction of action of terrestrial gravity.

3. A reactor as claimed in claim 1, wherein the axis is inclined with respect to a direction of action of terrestrial gravity.

4. A reactor as claimed in claim 1 or 3, wherein the axis is substantially perpendicular to a direction of action of terrestrial gravity.

5. A reactor as claimed in any preceding claim, wherein the trough is centrally located in the region of the axis.

6. A reactor as claimed in any preceding claim, wherein the trough is in the form of an annulus.

7. A reactor as claimed in any preceding claim, wherein the trough is centred about the axis.

8. A reactor as claimed in any one of claims 1 to 6, wherein the trough is not centred on the axis.

9. A reactor as claimed in any preceding claim, wherein the trough is undercut.

10. A reactor as claimed in any preceding claim, wherein a plurality of troughs is provided in the first surface.

11. A reactor as claimed in claim 10, wherein each trough has associated with it a feed means.

12. A reactor as claimed in any preceding claim, wherein the trough is provided with a matrix which serves to assist reactant in the trough to rotate with the support element when this is rotated.

13. A reactor as claimed in claim 12, wherein the matrix comprises a fibrous mesh.

14. A reactor as claimed in claim 13, wherein the fibrous mesh is made of a metallic material.

15. A reactor as claimed in claim 13 or 14, wherein the fibrous mesh includes a catalytic material.

16. A reactor as claimed in any preceding claim, wherein the collector means includes a receptacle in the form of a bowl or trough at least partially surrounding the support element.

17. A reactor as claimed in any preceding claim, wherein the collector means includes a deflector positioned about a periphery of the support element, against which product is thrown from an edge region of the first surface when the support element is rotating at an appropriate speed.

18. A reactor as claimed in any preceding claim, wherein the collector means is coated or otherwise provided with a catalytic material.

19. A reactor as claimed in any preceding claim, wherein the collector means includes means for heating or cooling product in the collector means to a predetermined temperature.

20. A reactor as claimed in any preceding claim, wherein the collector means is provided with feed means for adding a reactant to product collected therein.

21. A reactor as claimed in any preceding claim, wherein the collector means comprises a wall disposed on a periphery of the support element and extending from the first surface.

22. A reactor as claimed in claim 21, wherein the collector means further comprises a pitot tube which extends close to the first surface in the region of the wall and which serves to remove product from this region when the support element is rotated.

23. A reactor as claimed in any preceding claim, wherein the collector means is adapted at least partially to recycle collected product to the trough as feed reactant.

23. A reactor as claimed in any preceding claim, wherein the trough is coated or otherwise provided with a catalytic material.

24. A reactor as claimed in any preceding claim, including a plurality of support elements.

25. A reactor as claimed in claim 24, wherein the plurality of support elements is mounted on a single axis of rotation.

26. A reactor as claimed in claim 24, wherein the plurality of support elements is mounted on a plurality of axes of rotation.

27. A reactor as claimed in any one of claims 24 to 26, wherein product collected from a first support member is used as feed for a second support member.

28. A reactor as claimed in any one of claims 24 to 26, wherein feed means connected in parallel are used to supply reactant to each support element and in which collector means connected in parallel are used to collect product from each support element.

29. A reactor as claimed in claim 27, wherein a processing unit is provided between the collector means of the first support member and the feed means of the second support member.

30. A reactor as claimed in claim 29, wherein the processing means is a pump, an extruder, a heater or a heat exchanger.

31. A reactor as claimed in any preceding claim, wherein the feed means includes means for applying electromagnetic radiation or energy to the reactant.

32. A reactor as claimed in any preceding claim, further including means for applying vibration to the support member.

33. A reactor as claimed in any preceding claim, wherein there is further provided a rotary impeller or fan mounted close to the first surface and operable to generate a gaseous flow from a periphery of the surface towards a central region thereof, this flow being counter-current to a flow of reactant on the first surface.

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